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# ILLUMINATING ENGINEERING SOCIETY

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# Decorative Lighting—A Designer's Approach

By D. W. DURRANT (*Member*)


## Summary

This paper takes for granted that the technicalities of lighting are well known and therefore deals broadly with the aesthetic aspect. From the assumption that lighting is an integral part of interior-decoration, it examines the approach of a designer when dealing with a known interior, and compares this with the problem of designing fittings for a catalogue. It discusses the inveterate question of what is good design, and a definition is suggested.

In reviewing the trend of design, it refers to colour, form, light and shade, contrast and novelty, and considers the factors which influence changes in fashion, taste and technique. It includes an appraisal of some installations in relation to contemporary thought, and concludes with a plea for more good design and "lighting artists" in the industry.


## (1) Introduction

This paper bears the somewhat enigmatic title "Decorative Lighting" which, just before the last war, the Society defined as "the application of light where illumination must essentially be combined with artistic effect." Although I must confess that I was a party to this definition, it does not really make sense, as "artistic effect" cannot be isolated—it is integral to all good design irrespective of its field, and is thus a question only of emphasis of degree, often dictated by other considerations. If this is accepted, no form of lighting is excluded.

## (2) Limitations

### (2.1) Language

In any attempt to communicate thoughts about aesthetic appreciation in words alone, there is always the difficulty of the limitations of language, which no doubt is largely responsible for the clichés and jargon which so often invade articles or discussions on the subject. To the man in the street, such phrases obscure the issues and, instead of helping him to understand, merely try his patience and leave him confused and bewildered. This is nothing new; some 50 years ago it was written . . . "we live in a time of much printed fog about artistic things"(1).

Therefore, with the inevitable risk of over-simplification of a complex subject having its roots deep down in philosophy, religion and emotion, simple terms will be used.

### (2.2) Indivisibility of subject

Any study of lighting, whether or not the adjective "decorative" is applied, is inseparable from the study of the visual field. This has been admirably analysed in the report "The Design of the Visual Field"(2), and an appreciation of the scientific work described is an essential first step for all designers whose work is primarily associated with lighting. The conclusion, however, admits the intangible in the aesthetic result, and an attempt will be made in this paper to emphasise this aspect rather than the scientific side.

With such vast scope, it is necessary, and fortunately possible, to set limits to our subject, which will therefore be restricted to interiors in which decorative art is most easily demonstrated and understood. They are those which the majority of people find the most interesting and fascinating, those to which people go by choice rather

The author is with the General Electric Co., Ltd. The manuscript of this paper was received on January 18, 1956. The paper was presented at the Society's Summer Meeting held at Harrogate on May 11, 1956.

than because they must, those primarily for enjoyment rather than work. They include churches, public buildings, restaurants, places of entertainment and homes.

**(2.3) Illustrations**

As colour is such a vital component of decoration, black and white illustrations are completely inadequate, but since these must be used in the printed paper, they will be few. Although colour slides will be used in the presentation, it must be remembered that present techniques still make it difficult to reproduce accurately the effect of the actual installation. By using certain photographic "tricks," such as varying exposure or superimposed flash, it is, however, possible to get a reasonable approximation to the effect of the original.

## (3) The Problem Facing the Designer

**(3.1) Designing for an interior as a whole**

One instinctively thinks of the architect as the man responsible for the final appearance of an interior.

In early days, when the patrons of the Arts were the Church and Court, and a little later when these were supplemented by individuals who had the necessary money, it was quite usual for one man to be responsible for the appearance of the complete furnished interior, and in turn to be responsible to an individual as a client.

Nowadays, of course, the position is complicated by the substitution of the collective for the individual. The patrons are often big commercial or municipal undertakings, who commission large buildings which have become so complex in their services and the regulations applying to them that the architect can no longer be expected adequately to cover or control all the detail, and has then to employ many specialists to assist him; and these specialists are by no means limited to technical advisers. Many of them have to contribute to the visual appearance: the acoustics specialist may dictate the curve of a ceiling, the lighting specialist design the outside of a cornice as well as the fittings, and an interior decorator do all the colour work and design the furnishings. If all concerned are good designers, there may be no problem, and many solutions arrived at in this way are successful. But one weak link can, of course, ruin the whole from the aesthetic point of view, and spoil the good work of the others.

It is, however, logical to start by considering the design problem of the architect. As method is essential to study, we have to take the risk of endeavouring to break it down analytically under headings, knowing full well that each may be completely inter-related with one or more of the others. With this in mind, the problem is to provide a solution which—

(a) meets the convenience and habits of his client—the design must do the job for which it is created;
(b) is aesthetically harmonious;
(c) creates or complements a mood—providing the right "atmosphere";
(d) gives the designer personal satisfaction by making him strive continually to achieve a solution in a better way than has previously been possible, helped by the continual development of new materials and techniques, and by an ever-increasing legacy of tradition, knowledge and experience;
(e) is within the budget.

These are the limitations within which the architect has to work and, of course, without limitations there would be no such thing as design. Any solution is therefore a compromise.

This word has somehow acquired a stigma, as if it were something of which we should be ashamed, but in fact, everything is subject to and made possible by it.

It is an all-important element in design, not to be despised, but to be evaluated carefully, and we should all appreciate that design solutions are perfect if the precise optimum compromise is achieved.

I believe that the above five requirements form the basic problem of design which confronts a designer of anything; that all design problems, including those associated with lighting, have exactly the same broad terms of reference and the degree of success is a reflection of the competence and skill of the designer.

Maybe somewhat surprisingly, I have not included beauty as a specific requirement. This is because I feel that to a good designer ugliness is an error, and the more competent the designer, the more automatic is the creation of beauty. An adequate definition of beauty is elusive, but we all know that it is something which delights the mind and that, in spite of variations due to climate and race, it is an expression of what we term "aesthetic order." "Order" is the clue to understanding beauty, for man has evolved so that order pleases and disorder annoys. So much character and happiness result from the continual struggle to resolve contradictions.

Real beauty has a quality which survives time. We can to-day appreciate fine examples of painting, music and architecture of the past without it in any way lessening our appreciation of later efforts. Indeed, it has been stated that knowledge of dates is unnecessary for purely aesthetic appreciation[3]. But there is no doubt that pleasure can be increased by knowing the conditions and limitations under which the artist worked, and for this, knowledge of the historical background is essential.

**(3.2) Designing for an unknown interior**

Commercial considerations demand that the majority of lighting fittings be made in quantity and offered for sale, so that the designer responsible for them has no knowledge of where they will ultimately be used. A lighting fitting is unique in that it has two distinct appearances—when it is "off" and when it is "on," the lighting effect being a further and separate consideration. We cannot submit the lighting effect to a critical analysis in its own right in the same way that we can study a piece of furniture or a piece of music. It is important, however, to remember that we can do this with a lighting fitting itself; it is, in fact, a piece of furniture in the sense that it furnishes space as a complement to other decorative elements.

The designer has therefore to create his own hypothetical problem, restating it under the same five headings:—

(a) He must determine a purpose for the unit, the quantity and quality of illumination it shall give.

(b) There are no known factors with which the unit has to harmonise, so these have to be imagined. The unit must, of course, be harmonious in itself. A decision must be made as to whether the unit shall be dominant or subdued, particularly regarding colour finishes. As this is entirely a matter of relationship to its ultimate surroundings, it is often necessary to fall back on the device of alternative finishes, giving the client the choice.

(c) The mood will have been largely dictated by (a) or (b). He will thus know whether the fitting has to complement gaiety, concentration, reverence, sophistication or simplicity; whether it has to stimulate or soothe.

(d) He must ensure that the unit is mechanically and electrically safe, easily maintained, and so designed that it makes the maximum use of manufacturing techniques and machines commensurate with the quantity to be made.

(e) He must assess the price range and ensure good value.

More than one solution will be demanded, for not only will a particular design be used in many interiors, but many people will have similar interiors and want a different design.

Within everyone there is to some degree an inherent urge for individuality and

self-expression. Also, our dislike of monotony makes us tire even of good things. This may be no reflection on the design as such, and after a temporary change we can often come back to it as appreciative as ever. We simply like variety.

It is indeed fortunate for the designer that in spite of this, in any community there is a significant degree of conformity in many things, giving rise to what is termed the conventional, which gives some assurance that his design will please more people than himself.

## (4) The Designer's Approach

In the problem as stated, only the first and last requirements—most certainly the last—are completely factual. What equipment has a designer which enables him to produce a good solution to all five?

*Personal ability*

First and foremost is inherent artistic ability. Everyone may be born with a share of it, and whatever that share, it can be made more effective by training. But a share much more than the average is essential for a good designer.

This ability seems to quicken the designer's awareness of his environment; analysis of observation and perception becomes automatic. In particular he will follow new architecture and decoration. It enables him to discern and interpret the trend of design which evolves steadily through every civilisation, and distinguish this from fashion which swings rather as a pendulum, introducing vogues which develop quickly, go to extremes, and suddenly die. He will know about the theory and practice of colour, and find that much of what he learns he knows by instinct.

As an artist, he will appreciate form, texture, contrast pattern and the play of light and shade, and composition. He thinks in perspective, and has the power to visualise an empty shell as decorated, fully furnished and occupied. His urge to create acts as a constant spur to achievement.

*Legacy of the past*

The past is part of all of us, rich and full of achievement. In this country, as in many others, we have inherited much fine design in architecture and decorative art which, sifted and intelligently studied, give the designer tremendous help and inspiration. Every day adds to the enrichment of the collective experience available. The English Renaissance produced some lovely work, and the development of lighting fittings through this period has been the subject of a recent article[4].

*Scientific knowledge*

As a result of patient research, a vast amount of information is now available in published form. This need not necessarily be memorised, but can be referred to when required. It not only covers the mundane, such as properties of materials, but enters, perhaps gropingly at the moment, into physiology and psychology. It is factual equipment for the designer, such as no other age has had.

It is not really surprising that the number of outstanding designers is always comparatively small, and the amount of design work to be done is far more than they can handle. We have, therefore, to make the best use we can of less brilliant talent.

This brings me to two points on exercising our own choice in design, which is something no one with liberty of action can avoid.

(1) Most of us in the lighting profession—and I use this word deliberately rather than "business"—are often asked for advice by people who are genuinely seeking guidance on appearance as well as performance, and if we are completely competent as advisers on lighting, we should be able to give it. It is an important aspect of our job, and I have no patience with anyone who says "I would not dare to give it due to personal taste." Of course there is taste,

or there would only be available one design of everything; but the real issue is between good and bad design. Maitland Graves has produced a standardised Design Judgment Test(5) which, it is claimed, can evaluate your ability in this respect.

(2) The other concerns the question "If people are happy with bad design, why should we worry?" Several arguments can be used as to why we should, but the simplest is the fact that people mature as they grow older. To-day, with our unprecedented means of communicating ideas—books, Press, radio, and, I think the most important of all, television—knowledge and appreciation of culture is being disseminated to an ever-increasing number of people at an extraordinarily rapid rate. They realise that many things which pleased them once no longer do so, and they become painfully if slowly aware of the shoddy. I submit that if at the outset they had had only the choice of good designs, they would have found something equally to suit their taste, and later disillusionment or disappointment would have been avoided.

It is also fortunately true that pieces of good design have a habit of harmonising, whilst good and bad will always be aesthetically incongruous.

A particular difficulty exists when dealing with the majority of normal homes, particularly those with open planning or restriction of space which demands multi-purpose rooms involving diverse moods.

There is rarely an architect, and the interior decorator is the husband who actually climbs the steps and wields the brush, whilst the furnishing consists of pieces bought over a period of many years. In addition to the inevitable wedding presents and the like, these things have all been chosen by one or more of the family because at the time they thought they liked them. With each purchase there is a personal association or sentiment which, however indefinable, becomes a real part of the object to that particular individual alone.

Many people will also say they know what they like but are quite unable to analyse why. Some refer to "instinct," many copy or follow advice from friends and acquaintances no better qualified, others rely on vague recollections of "matching." It is therefore not surprising that comparatively few of our homes can be classed as good design; many are mediocre, mousy and what are described as "safe," and some just bad. Most people, I think, would like to try to make their homes more exciting, but are driven into the "safe" by lack of knowledge and the cost of failure. They require only a little moral support; and those of us who have to design fittings or direct a design policy have a responsibility to ensure that our work helps to raise the general level of design.

## (5) Trend of Design

The current trend of design is a sane one, and although its aspects are inter-related, some method of separation must be employed in order to discuss them.

### (5.1) Colour

This subject has received a great deal of attention from the physicist, physiologist and psychologist. We realise that what we see with our eyes is rarely what we see with our mind(6). We know that a given colour, precisely defined by its spectrophometric curve, can look completely different according to what other colour immediately surrounds it. Further changes occur according to the colour of the illuminant, so that daylight, incandescent lamps and fluorescent lamps give a wide range of results. These factors have led E. W. Commery to the conclusion that the only satisfactory way of obtaining good interior decoration under the lighting conditions with which they will be used is to work with large samples(7), and in practice many designers employ this

method as far as it is practicable. The colour wheel may be old, but it is still a useful practical aid.

Whether in spite of or because of this increasing knowledge, colour is being used more boldly. Many lighting fittings are available which are suitable to be used as an accent in a general colour scheme, and have relatively substantial areas painted in good clear strong colours, such as red and black. Some translucent shades have a very low brightness background with panels which, when illuminated, glow with an effect rather like that of a stained glass window.

The introduction of such points of strong colour to an otherwise drab interior will usually improve it considerably, and impart a sense of luxury which is absent from the conventional.

**(5.2) Form**

Form is closely related to materials and techniques. In keeping with a similar trend in architecture and furniture, heaviness is no longer considered an essential of quality; neatness and lightness are preferred as more appropriate to contemporary outlook.

As a result of a more rational use of materials, basic shapes tend to become simpler, thus adding importance to refinement of line and proportion. The replacement of skilled craftsmen by machine processes appears inevitable, and as this is only economic when articles are made in large numbers, the designer should receive every encouragement to make such mass-produced shapes really good design. It is in the interest of our industry to do this, as well-designed articles should maintain their sales for a longer period of time than mediocre ones. This should reduce overall costs and enable more people to buy them.

Symmetry, for so long the generally accepted basis of form for lighting fittings,

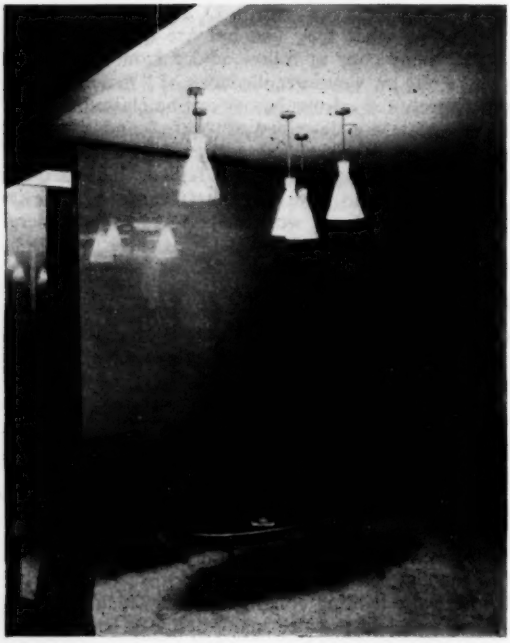


*Fig. 1.*

is being successfully challenged by asymmetrical free arrangements with their greater degree of visual interest (Fig. 1).

Prior to the last war, the vogue for functionalism produced much that was cold unfriendly and devoid of ornament. So much emphasis was placed on the scientific aspect of "fitness for purpose" that the emotional side of complementing the mood tended to be ignored. Happily this phase of sterility has passed, and ornament, once more recognised as both necessary and justifiable, is being used intelligently—not too much and not too little. Its character has become refined rather than ebullient, and both geometric and natural forms have their appropriate applications.

**(5.3) Light and Shade**

The better appreciation of light and shade is contributing almost as much as colour to giving more visual interest to interiors. Perhaps the most obvious trend is the virtual disappearance of the completely indirect lighting scheme, due to its monotonous and flat effect. Pools of light and shade, and sparkle used rather as high lights as by a painter, now tend to liven the scene. To many, a ceiling of relatively high even brightness is considered undesirable. The use of small recessed fittings in an acoustic tiled ceiling can produce a surface and brightness pattern which is a decorative element in its own right, quite apart from its function for illumination.

**(5.4) Contrast**

A fundamental of interior decoration is that in order to have points of interest, there must be places where there are none, and the right balance of contrast is essential to success. This most important principle applies to colour, pattern, texture and brightness. By the use of contrasts, modern decoration can avoid the worrying and restless effect of Victorian interiors, where something seemed to be "going on" in all places at once.

The use of contrast is being enormously assisted by the increasing variety of pattern and texture now available. The intrinsic patterns and textures of natural and manufactured materials are well known, but these are being supplemented by textures arising from other considerations. Two examples are the familiar pierced acoustic tile, and a floor tile which has a surface of embossed discs to prevent slipping and marking.

**(5.5) Novelty**

At any time of vitality there is the urge to experiment and it is therefore inevitable that some novelties should appear. Lighting fittings are by no means exempt, but novelty should not be taken seriously as an aspect of the trend of design. This is not meant as a sweeping condemnation of it, as it can be welcomed if employed with restraint. Two random examples are the use of craft materials for lampshades, and metal reflectors which are so small that they burn your fingers. Neither can be logical or practical for what is usually considered a reasonable life for a fitting, but both may often be accepted on the grounds that the limitations are a fair exchange for the stimulus of something unusual.

## (6) Examples of Solutions

Many papers are presented to the Society which deal in detail with installations of lighting, usually with emphasis on the technological aspect. During the last few years Baines[8], Hubble[9], Claude[10], Young and Misselbrook[11] have discussed lighting installations both from the scientific and aesthetic viewpoints, and Medd has dealt with colour in schools[12]. In the following examples I am taking it for granted that the technicalities are well known, so they will form no part of my comment. Also, as all are factual installations, they must have met the budget. In relation to what has already been said in this paper the illustrations should speak for themselves. It must, however, be remembered that it is quite unfair and often inaccurate to judge

*Fig. 2.*

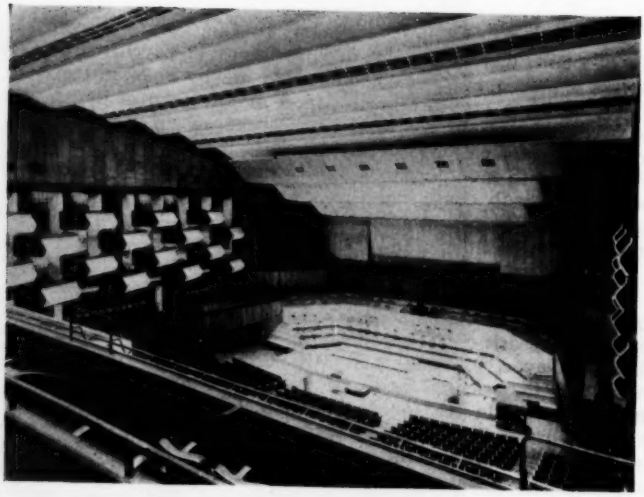


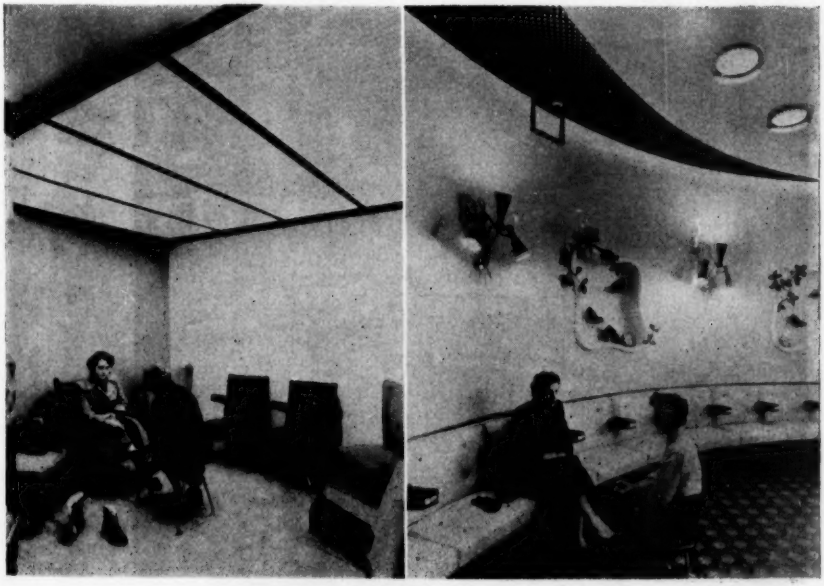
*Fig. 3.*

an installation on the evidence of a photograph, especially without colour. The camera may also include only a small part of the normal field of view, and its relation to the whole is therefore completely ignored. This can be a particularly misleading factor. We can therefore only comment on an interpretation of the photograph itself.

Since the war London has been fortunate in getting two outstanding buildings which are world famous as examples of decorative art, the new House of Commons (Fig. 2) and the Royal Festival Hall (Fig. 3). They have been reported fully[13], but as they represent completely successful solutions of the integration of lighting and architecture in two widely differing styles, I feel no excuse is necessary for illustrating them again.

Figs. 4 and 5 show two solutions for the same mood, and both rooms are without windows so that the conceptions are based only on using artificial light. Fig. 4 represents a conventional solution relying almost entirely upon colour and texture for interest. As seen in the photograph, the shell lacks any decorative focus, and the even brightness of the ceiling draws the eye without there being anything interesting to look at. As with indirect lighting, the tendency to flatten is quite apparent, and the atmosphere tends to look cold and impersonal. Note the lack of modelling.

Fig. 5 shows another solution, for the same mood, which makes an altogether different approach and results in a more lively and friendly interior. The ceiling has a general brightness comparable with the walls, which has a unifying effect on the curved and flat surfaces. The form, colour and lighting effect of the wall brackets play their complementary parts in making the fittings points of visual interest. The shape of the room is an important feature of the conception, and emphasis is obtained by change of colour, texture, pattern and brightness round the edge. The continuous slab provides a perfect balance and the heavy shadow relates it to the floor. Note



*Figs. 4 and 5.*

*Fig. 6.*

*Fig. 7.*

how the asymmetric shape of the recesses and wall brackets is balanced by the regular pattern of their positions round the wall.

Figs. 6 and 7 demonstrate the trend of design. Both rooms are in the same building recently rebuilt, and standard lighting fittings are used. A requirement for the interior shown in Fig. 6 was that it should be a transitional link between the previous building and the new one. The cottage-type furniture, the bar and copper ornaments retain the old atmosphere, whilst the wall treatment, fireplace and fittings are modern. Fig. 7 illustrates a completely contemporary interior. The bolder colour scheme can be imagined, and the greater use of contrast in texture, pattern and brightness can easily be seen. Note the lightness and neatness of the furniture compared with Fig. 6. It is an interior of much greater visual interest.

The two views of the interior of a small church (Figs. 8 and 9) show how the

*Fig. 8.*

*Fig. 9.*

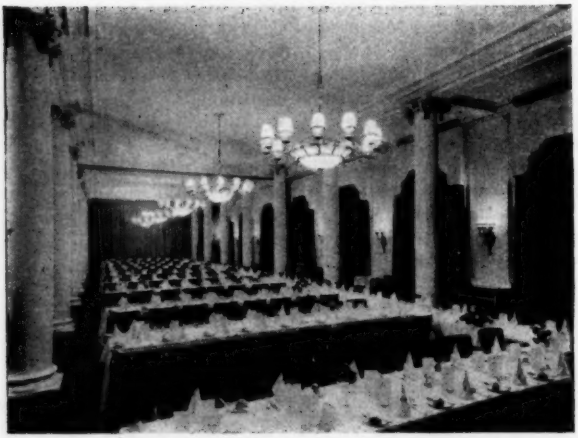


*Fig. 10.*

intelligent use of directional lighting and contrast can reveal the form of architecture. The walls and ceiling are near white and the altar cloths provide a focal point of colour. A coherent flow of light across the church and chancel has been achieved by restricting the light sources to the south side. The play of light and shade on the altar and on the mullions of the east windows makes their solidity apparent, and Fig. 8 shows clearly how the high-lighting on only the left-hand side of the chancel arch reveals the form and character of the moulding. By using higher brightnesses on the surfaces seen through all the arches the shapes are defined, and the effect is subtly emphasised by slightly altering the colour of the light in the nave compared with the rest of the church..

Fig. 10 has been included to illustrate how lighting-fittings can be used to furnish space. The room is used for dinners and dances, both of which require a friendly atmosphere, and the mood for dancing is more intimate than for eating. The architecture can hardly be said to assist this, but rich, warm curtains and carpets are helpful. The detail of the large chandeliers is harmonious with the architecture, and their wide spread and brightness form a barrier of interest which was used to detract from the height of the ceiling. Pleated silk shades and silk-covered suspensions provide the rich softness which was wanted and which was lacking in the combination of metal and glass only. For dancing, the light can be reduced and warmed by switching from white to pink-coloured lamps in the centre bowls, with or without the candles. The brackets are obvious centres of interest and ornament on a long wall of unpatterned surfaces, and their lighting effect on the wall emphasises this function.

## (7) Conclusion

It is rarely wise and often impossible to predict the future, but I am confident that the trend of design is towards better lighting. We are all aware that we have to serve people who differ widely in requirements, incomes, taste, education and æsthetic appreciation. I see no reason why good design should not appeal to them all, although differing styles will be required. Certain people still have a fear that contemporary designs may have a transience which may date them even to a particular year, and often expensive buildings can be redecorated only at infrequent intervals; in such cases preference may well be shown for a proved quality of elegance although it may be a century or more old.

From what I have said, good lighting depends on good designs, and if the function

has to be divided, it is merely stating the obvious to say that full co-operation is a fundamental necessity. I share the view that at the present time the industry has a great need of many more "lighting artists" if we are to make a contribution to æsthetics commensurate with our opportunities.

Having reached this stage of my paper, I confess to being uncertain whether I have said too much or too little, and whether I have managed to convey in print my enthusiasm for a subject which to me abounds with opportunity, fascination and enjoyment. I can only hope that others, irrespective of their bent, find in it equal delight.

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## Discussion

MR. C. W. M. PHILLIPS: I rather feel that it is almost impertinent of me to say anything at all after this wonderful paper. We have actually had two papers, the written one and a series of demonstrations and slides the like of which I do not think I have ever seen before. The reason I am opening the discussion is that I have a great personal admiration for the author and for his work. I have no ability whatsoever in the matter of design myself, but I think that we have all learnt how to recognise good design from some of the things the author has shown us.

If there is one thing I am sorry about in this paper, it is that Mr. Durrant dealt entirely with what one might call lighting for leisure, the inference being that decoration or good design is only necessary in those places where we relax and enjoy ourselves. I think perhaps we manufacturers have a great responsibility towards the public, towards our customers, towards civilisation almost, in the improvement of the design of those catalogue products that we offer for, shall we say, offices and factories and places where we work. I have found that the biggest problem in introducing good design into this type of product is the difficulty in marrying up the outlook of the artist and the requirements and outlook of the electrical, mechanical and production engineer. There seems to be a feeling that the born designer, if one may call him such, either comes in right at the very beginning and sets the electrical and mechanical engineer an impossible job, or he comes in at the end and is set an impossible job by the electrical and mechanical engineer. Mr. Durrant seems, in his own personality and ability, to have all the characteristics that are needed for a first-class designer.

I wonder if any of you here have got any thoughts you might care to ventilate which would enable us, as manufacturers, to bridge that gap between what one might

call the demand for a delightful, attractive product, and the demand for a product that works and can be made at a very cheap price?

MR. A. G. PENNY: I think this problem Mr. Phillips has mentioned, of persuading the electrical and mechanical engineer and the artistic designer to work together, either in series or in parallel, is a fundamental one. I suggest, however, that, in principle, it is a simple one to solve. So long as the designer can understand and appreciate that the electrical and the mechanical engineer has a job to do, and so long as the electrical and mechanical engineer can understand that there must be an artistic designer somewhere in the proceedings, then I think, provided they respect each other (not try to do each other's job), that the problem is likely to be solved. I think that in the I.E.S. we have the opportunity given to-day by Mr. Durrant to show the electrical and mechanical engineers here some of the problems that must be dealt with before the finished product can be satisfactory, and given this morning by Ferguson and Stevens, as an example to the artistic designer of what has to be known and what are some of the problems that have to be solved before his designing can be turned into something useful as well as elegant.

DR. H. H. BALLIN: Whether by design or by coincidence, we had a most interesting example of two aspects of the same problem in the first paper of this session and the last paper. In the demonstrations by Dr. Strange we saw a domestic interior with flexible lighting by means of various built-in devices and by the possibilities of adjusting the lighting levels. The display by Mr. Durrant has shown us the more-or-less static set-up more common to-day with a fixed ceiling point, and a few plug points, and the possibilities of interesting and varying lighting in this way. It may be that the answer for the ultimate consumer lies half way between, and perhaps all of us who have seen both demonstrations have noted a few points that we can take back with us and will try in our own homes.

One thing struck me particularly: the display of lighting fittings we have seen this morning. There was not one I would have wanted to live with forever, but there were quite a few which I thought would be great fun to have for a month or two, or six months, or perhaps even a year; and that goes just as much for the more conventional styles as for the modern ones. There is, I think, something to be said for changing the lighting in the home from time to time. Some of these "frivolous" new designs give more scope for variety than the elaborate and conventional types which obviously cost very much more. I think there is a lesson to be learned from this point.

One point on the slides. They were, perhaps, a little unjust to the achievements which have been made in integrated lighting in this country: I think the only really good examples where lighting was part and parcel of the total architectural design, came from overseas, from France and Singapore. We have very good installations in this country where, by co-operation between architect and lighting engineer, satisfactory results have been obtained.

MR. F. H. PULVERMACHER: In none of the examples shown so splendidly this morning was there a fluorescent fitting. I should like to know whether the author's comments on fluorescent lighting for domestic interiors are publishable?

MR. P. E. C. SMITH: I am a little dazed by the wonderful display of coloured photographs and by the demonstrations, but my imagination has been stimulated by some of the statements made in the author's paper. The first aspect of the paper that struck me was his obvious concern over training designers. I have heard this

expressed in a number of widely different fields. I am afraid designers are born and not made, and they are comparatively rare. A talent for design, to my mind, is an ability to sum up the several factors concerned in a particular sphere, and the person who can do this and produce the right solution is a designer born, and I am afraid he can very rarely be made by training.

As far as lighting fittings are concerned, in a big organisation, particularly a semi-industrial organisation, the difficulty confronting the person responsible for providing lighting fittings for such an organisation is to select a relatively few types from the comparatively large field which is available to-day. It is possible, I think, to meet the demands of a large semi-industrial organisation by a relatively small number of fittings and I think the main factor to be kept in the forefront all the time is simplicity. If you bear in mind that you have got to do what you want to do in the way of achieving efficient lighting in the simplest possible manner and at the lowest possible cost, you will not go far wrong. You can choose to-day a relatively small number of fittings for such an organisation and achieve your object, and also, I think, satisfy the architects, perhaps the main party to satisfy in the problem.

MRS. E. B. SAWYER: As one who criticised contemporary lighting two years ago, I would like to congratulate all the people who have made an effort in the last two years. Mr. Phillips said that we should try to produce something cheaper, but I am not sure that he is right. We now have the good designs and we have light sources, but could we now in the modern and contemporary fittings, have a little more quality? It does not seem to me that it is altogether design you get tired of; it is often the cheapness of the design.

MISS I. E. JACKSON: I have not heard any mention about the size of the room to be lit; there seemed to be a tremendous number of fittings in each room demonstrated. You can have far too many in a tiny room—and then there is little space for anything else. Fittings must be chosen according to the size of the room and the purpose for which it is used.

MR. G. E. KEMP: I was glad to hear a speaker mention the difficulty of providing fittings for the modern domestic scene. There are so many millions of houses these days with ceilings about 8 ft. 6 in. high and it is very difficult to provide respectable lighting for these ceilings.

At a previous meeting I referred to lack of mechanical design in lighting fittings and I think that this is a still more important point in some of the types of fittings which our lecturer has shown to-day. The period type of fitting with decoratively curved tubing is so often difficult to wire at the premises where it is to be erected and so few manufacturers make any provision for getting the necessary wires along the tubes. It was all right to push gas along them, but often you cannot push flex through them. It is also very necessary to provide a smooth entrance to these tubes: I have seen so many flexes badly chafed through rough ends and interiors of tubes. Bushes have dropped off after a few months' use and so often a very beautiful fitting becomes spoiled after a short period of use because the lock nuts used in this type of fitting are difficult to tighten and readily slacken off and the delicate bends and curves of the fitting become displaced through this slackening off.

One final point on the slides illustrating church lighting, one of which I noticed in particular. I know it is difficult to judge from slides, but it did seem to me that the central feature behind the altar was extremely bright and I do find it very difficult in church constantly to look at the preacher against a very high background brightness

or underneath opal or other suspended fittings which from the rear of the church or from the balcony are at a very narrow angle to the line of sight.

MR. C. C. SMITH: I would like to follow the lead of a previous contributor to a discussion, earlier this week, who said that he was a lamp maker pure and simple; I am a street lighting engineer pure and simple. Nevertheless, I would like to emphasise what I think is one of the most important points this most excellent paper and demonstration have brought out: that is, the fact that you can do such a great deal with one central ceiling position, and perhaps two or three socket outlets. I have read reports which state that in America it is quite customary, in the ordinary six roomed house, to have as many as 65 socket outlets. I would like to know what the speaker feels about the necessity for such a large number. It would appear to me, from what we have seen this morning, that a great deal can be done with far fewer.

With regard to the problem of the designer and the engineer, I think we have seen the complete solution this morning. The gap has been bridged in the form of our author, who is both combined in one. I think probably that is the answer.

MR. E. RADFORD: Mr. Durrant began his paper by referring to Gothic architecture: the earliest style being generally known as Geometric. Through improvement in craftsmanship this style gave way to the Decorated and Flamboyant through several centuries. With the advent of the Black Death most of the skilled craftsmen were lost and in due season a more formal style developed, termed the Perpendicular, in which we find the finest example in Britain at King's College, Cambridge.

It would seem that this phase of history has been partially repeated, in that, up to 150 years ago we enjoyed an ordered and formal progress in architecture culminating in the Georgian period together with a style of lighting fitting which represents, to my mind, the best that we could have. Grotesque Victorianism has given way to stark form termed "Contemporary" criticised justifiably by some as "Contemptible."

Lack of good taste is encouraged not only by some designers, but by the buying public. Our motto: "To Spread Light Everywhere" should be carried a stage further, namely, to spread the light of good taste.

Mr. Durrant concluded his remarks by referring to elegance and that criterion should really influence our criticism and appreciation of decorative lighting and lighting fittings.

MR. DURRANT (in reply): My first duty is indeed a pleasant one. It is to publicly thank Messrs. Denby and Spinks of Harrogate for their co-operation in loaning the furniture for the stage sets; then Miss Joan Wood, from the staff of *Light and Lighting*, who added such charm and grace to the finale; and lastly my colleagues who have put in so much hard work behind the scenes. I am most grateful to them all.

May I also make a composite reply to the many interesting points raised in the discussion.

I fully agree that design is an important factor in all fields, and the opening of my written paper makes reference to it varying only in degree.

I also agree that many of the slides, though perhaps not as many as implied by one speaker, showed installations from overseas, but the time allocated for this paper imposed a severe limit on the number which could be shown. As the stage demonstrations were almost exclusively British made fittings, I made a deliberate decision to include a fair quota of overseas practice in the illustrations. Each was selected to illustrate a particular point of design, and I think demonstrates that in spite of differing local environment, to-day's communications have made design very much an international subject.

Are fluorescent fittings suitable for the home? I prefer to make the approach from

the other end, namely, the suitability of the final result. If fluorescent tubes are the most convenient method of obtaining the required result, then they are suitable. Several examples were shown on the screen, with my comments on the results.

I agree that designers are born and not made. The point I made in my written paper was that everyone has some artistic sense. Only those who have far more than the average can make designing a career, but it is still true that whatever the degree of artistic appreciation it can be made better by training.

The questions of quality and of price have been raised. In a certain type of magazine I am constantly assured that five minutes of "do it yourself" applied to a bargain always obtainable for a few shillings from the local second-hand shop will give me just what I want. Alas, my experience is that in this world you get just what you pay for. Good design, which if it is good will provide ease of wiring, ease of cleaning and reliability, can be obtained but not necessarily at so low a price as a similar-looking fitting which is deficient in these "hidden" values. The answer must lie in the relative importance given to the price as a design limitation and the exercising of discrimination when buying.

The size of room and the mood for which it is to be used are obvious bases from which to start designing; again I lay emphasis on composition, and as a final test of the installation, both for quality, quantity and everything else, if it satisfies my five tenets, I am prepared to say it is good.

Another speaker mentioned the high brightness contrast in a church shown on the screen. The slide was put on to illustrate this point, and in answer to the question I would say that in that type of church the pulpit is usually separate and away from the altar, so I do not think he would be worried by having to listen for any length of time to a speaker standing in front of that focal point. I know of one installation in which the lighting intensities can be changed during the service so that the visual focus shifts between altar and pulpit as the occasion demands.

In the demonstration, time and space restricted the number of points which could be used. In principle I am in favour of having the maximum number of points as can conveniently be got in. Although obviously they will never all be in use at one time, a large number is the most convenient way to achieve flexibility, and of course their use need not be restricted to lighting. Such an arrangement helps to meet our liking for variety. However good our choice of designs, the time comes when we tire of them, and want a rearrangement, just as we do with our furniture layout. With good design, however, we can come back to it with as great appreciation as before. Many points also enable us to experiment reasonably easily, and this I would encourage.

The last speaker considered the end of the Renaissance to be a climax of good design, and few will quarrel with this as far as interior decoration is concerned. However, it is not the first or the last, and I am therefore not particularly concerned with dates. My view is that good design is practically independent of time, and retains its power to delight us all. It is the possibility of this achievement which to me makes lighting such a fascinating and enthralling subject, and one which can give so much enjoyment to so many.

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## Additions to the List of Members

The following applicants have been duly elected by the Council to membership in the Society and their names have been added to the list of members:—

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## Binding of Transactions

Arrangements have been made with a firm of bookbinders for members of the I.E.S. and subscribers to have their copies of the Transactions bound in uniform style. The binding is in dark green cloth with the title, volume number and year in gold on the spine.

The cost is 8s. 6d. including return postage in the U.K. The binding is of excellent quality and has been approved by the General Purposes Committee of the Society.

Those wishing to have their copies bound, one year per volume, should send them direct to the binders (*not* to the I.E.S.) together with the index and cheque or postal order for 8s. 6d. per volume. The address is: **P. G. Chapman and Co., Ltd., Kent House Lane, Beckenham, Kent.** (If an index is not enclosed this should be mentioned.)

A limited supply of copies of the Index for the 1955 volume is available from the I.E.S. for those who have mislaid the index which was included as a loose sheet in issue No. 9, 1955. A limited number of copies of individual issues (price 1s. 6d. to I.E.S. members, 5s. to non-members) are also available to make up complete volumes.

Spring-back binders to hold copies temporarily during the year of issue and before permanent binding are available from the I.E.S., price 6s. 6d.

# Light Sources for Colour Matching

By E. E. MILES, B.Sc., A.Inst.P., and D. C. PEACH


## Summary

Visual comparison of the colour of an article with a colour standard forms the basis of colour control in many industries. While the colour of the sample and the standard will only be a true match if their spectral reflectance characteristics are identical, this is not always practicable and the problem facing the colourist is to obtain the best match under the widest range of illuminants. North overcast daylight is generally regarded by colourists as being the most satisfactory source. The general characteristics of daylight with particular reference to variations in colour, the conclusions reached in surveys conducted to determine the preferred characteristics, and the variations between observers in determining a colour match are discussed. The matching of colours having a fluorescent component and the matching of fluorescent whites are also discussed. Artificial light sources which are available for colour matching work are compared. A source combining tungsten filament and fluorescent lamps which reproduces the required conditions is proposed.


## Introduction

In many industries such as textile dyeing, colour printing, paint and paper making, colour matching is an essential part of the processes involved and visual comparison of a sample with a colour standard forms the basis of colour control. A number of instruments for the objective measurement[1, 2, 3, 4, 5] of colour to a reasonable degree of accuracy have been developed during the past 20 years; but the somewhat higher accuracy, speed and simplicity of visual comparison by professional observers ensures widespread use of this method for many years to come.

It is the purpose of this paper to discuss some of the more important factors affecting the visual observation of small colour differences and the most suitable artificial light sources for these observations.

The sample and standard will be a true match only if their spectral reflection characteristics are identical. This is normally true if the two colours are produced from the same basic colouring ingredients and if the surface textures are also the same. They will then match under all forms of illumination. This applies in the routine inspection of different batches of production in industry, where a standardised range of pigments or dyes is used, made to close specification and incorporated into a base material which is itself closely controlled. Frequently, however, the sample is not produced to the same formula as the standard and the spectral reflection curves are slightly different. This metameric matching, where the spectral reflection curves are not identical, may occur, for example, when an artist's design in water colours has to be reproduced on a fabric or wallpaper, or when the same subjective colour has to be produced in two different types of base material, e.g., plastic buttons to match a cotton or woollen material. The problem facing the colourist here is to determine whether the colour appearance match of the two articles is sufficiently close to be acceptable under normal user conditions.

These user conditions can be specified under the broad headings of daylight and artificial indoor lighting. The latter is mainly light from incandescent tungsten lamps operating at about 2,800 deg. K, or from fluorescent tubes of one of the white colours available commercially.

Tungsten filament lamps of around 2,800 deg. K colour temperature are frequently used by colourists for comparison purposes, and the small spread in spectral distribution due to supply voltage variations and variations in the lamps themselves presents no serious problems. The spread in the spectral characteristics of daylight is however

Communication from the Staff of the Research Laboratories of The General Electric Company Limited, Wembley, England. The manuscript of this paper was first received on December 8, 1955, and in revised form on January 23, 1956. The paper was presented at a meeting of the Society held in London on March 13, 1956.

very considerable, and the provision of an acceptable artificial substitute for daylight, which has the preferred colour temperature and which is simple, efficient and constant, has proved a very difficult problem.

## Characteristics of Daylight

The ultimate standard of illumination generally used at present for colour matching work is daylight, and through years of experience professional colourists have come to regard certain daylight conditions as preferable for their work. The quality of daylight depends, amongst other factors, on the time of year and day, geographical latitude, and amount and type of cloud or haze present. A number of surveys have been made in different parts of the world on the variation in quality of daylight[6, 7, 8, 9] which, when expressed in terms of equivalent colour temperature, show variations from 3,000 deg. K for direct sunlight to 26,000 deg. K for clear blue sky.

## Preferred Daylight Characteristics

A detailed study of the preferred viewing conditions in the United States has been carried out by Nickerson[10], with particular reference to cotton classing. This worker found that a light overcast sky was preferred, with an average colour temperature of 7,500 deg. K for a minimum level of illumination of 100 lm/ft². The conditions considered good by the colour matchers in this study varied from around 5,900 deg. K, with an illumination level of 300 lm/ft², to 25,000 deg. K at 100 lm/ft².

In this country, the preferred conditions appear to be closer to 6,500 deg. K and it might well be expected that the preferred average equivalent colour temperature will vary from country to country, depending on the variations in the daylight conditions prevailing. It is also a feature of cotton classing that colour gives some indication of the degree of fineness of the raw cotton or staple and, as the American surveys have mainly been associated with cotton, this may be a secondary reason for the preference for a higher colour temperature. The spread in conditions described as "good" indicated that, provided an adequate level of illumination is used, the precise colour temperature of the daylight does not appear to be very critical. The spectral energy distributions of different phases of daylight and a full radiator at 6,500 deg. K are shown in Fig. 1.

In this country, the daylight illumination for colour matching work is usually

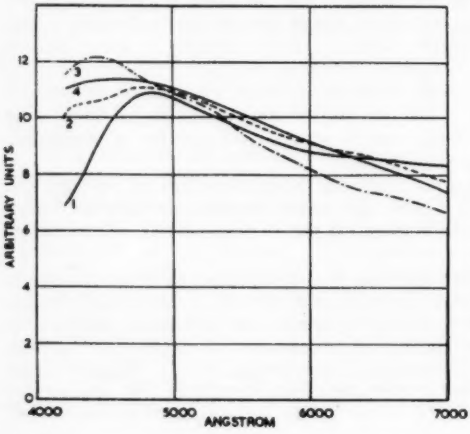


*Fig. 1. Spectral energy distribution of*
*1. Sun and skylight.*
*2. Lightly overcast sky (6,500 deg. K).*
*3. Lightly overcast sky (7,500 deg. K).*
*4. 6,500 deg. K full radiator.*

provided from a north-facing window, preferably illuminated by a lightly overcast sky. The window should be situated so as to avoid reflected light from surrounding buildings or trees falling on to the working area. The samples are placed either on a bench, or held at an angle to prevent preferential reflection from the sky. An important feature of daylight is the large diffuse nature of the source, which is particularly advantageous when viewing surfaces which are glossy.

With the increased use of materials having various degrees of fluorescence, the ultra-violet content of daylight also becomes an important feature. Many white fabrics now have a blue fluorescent dye incorporated in the material to increase their apparent brightness and whiteness; the matching of these whites under artificial sources presents special problems. The fluorescent materials are excited by blue and long wavelength ultra-violet radiation, and the absorption of the shorter wavelength ultra-violet in daylight by the window glass does not have any noticeable effect on colour or brightness.

In addition to these variations in daylight, the spectral composition of the reflected light is modified by the observer's eye, and this differs between observers, even though they have normal colour vision.

## Observer Variations

The most important of these variations is that usually attributed to absorption in the eye by the macular pigment. The effect of this in practical colour matching appears to be very similar to that of variations in the colour temperature of the light source with a constant observer. Wright([11]) has obtained the chromaticities of different stimuli for a number of observers, and found the spread in the measurements made in a visual colorimeter of any given stimulus to be greater than could be accounted for by the errors of observation.

Warburton([12]) correlated the degree of macular pigmentation with age of the observer; the greater the age, the greater being the amount of pigmentation. In other words, the apparent colour temperature of a given source decreases with increasing age of the observer. Warburton used for his test a dichroic (standard pattern, that is, a dye having more than one peak in its spectral reflection curve) which was matched against one of a numbered range of dichroic patterns dyed with dyes different from those used for the standard, the position of the match varying with the observer and the illumination under which it is used. The 13 patterns in the range varied in hue from a dull green to a reddish brown and appeared redder in tungsten filament light than in daylight, whereas the standard appeared greener. Observers were asked to select the pattern on the range which gave the best apparent match to the standard pattern.

Warburton's work has shown that the effect of pigmentation, even in people with normal colour vision, could be equivalent to a variation of 3,000 deg. K in the colour temperature of the incident illumination. However, 60 per cent. of these observers selected one of two adjacent sections corresponding to a variation of $\pm$ 250 deg. K in the colour temperature of the incident illumination, so that the selection of observers for professional colour matching should not be difficult and is strongly recommended by Warburton. With such selected observers, increased accuracy of colour matching should be possible but there will then be a corresponding need for a source of closely controlled characteristics.

The sensitivity of the eye to small colour differences increases considerably with the area of the sample, particularly when they are viewed side by side, and it is desirable that the samples should subtend an angle of at least 10 deg.([13]) at the observer's eye. The colour sensitivity of the eye also increases with the degree of acclimatisation of the observer. If observations are made in a localised area, the general surrounding illumination should be of a similar quality to that of the colour matching source and,

to avoid eye fatigue in specific spectral regions, extraneous colours should be removed from the field of view. An obvious precaution is to ensure that the surrounding wall decorations do not affect the spectral quality of the light falling onto the sample under test.

## Artificial Sources

It will be clear from what has been said that, for the best viewing conditions for colour matching under artificial illumination, it is desirable that the whole working area should be illuminated to the required level with a source having spectral characteristics close to those of a full radiator at a colour temperature of about 6,500 deg. K. In general the level of illumination should be at least 100 lm/ft$^2$ on the working plane, but when darker colours are being examined a level of 300 lm/ft$^2$ is desirable.

It is essential for accurate matching that there be sufficient luminosity from the sample in the spectral region of minimum reflection to enable the effect of these subsidiary radiations from the sample to be examined accurately by the observer.

Taylor[14] has suggested that a source rich in a colour complementary to that of the samples should be used, but this is not generally practicable owing to the wide range of colours encountered during the course of everyday work.

The achievement of these high levels of illumination is, however, limited in practice by economic considerations. Before 1939 several installations of Moore high voltage carbon dioxide discharge tubes were in use, where the tube was formed into a grid to extend over the whole ceiling. While the visible light emitted by this source comprises closely spaced lines and bands, the spectral distribution is close to that of a lightly overcast sky at 6,500 deg. K, as shown in Fig. 2.

Unfortunately the carbon dioxide gas cleans-up during use and some replenishing device is required. In large installations the gas replenisher took the form of a metal cylinder with reducing valve, which admitted carbon dioxide to the tube at the same rate as the gas cleaned-up. Alternatively, in the smaller tubes the carbon dioxide was provided from a side tube containing a carbonate stick surrounded by a heater coil. The heating of this coil was arranged to liberate carbon dioxide, at the correct rate, by thermal decomposition of the carbonate. These tubes had a luminous efficiency of about 2 lm/w and, with the development of higher efficiency and less costly sources, the carbon dioxide discharge tube has become obsolescent.

Colour matching units employing a high wattage tungsten lamp in association

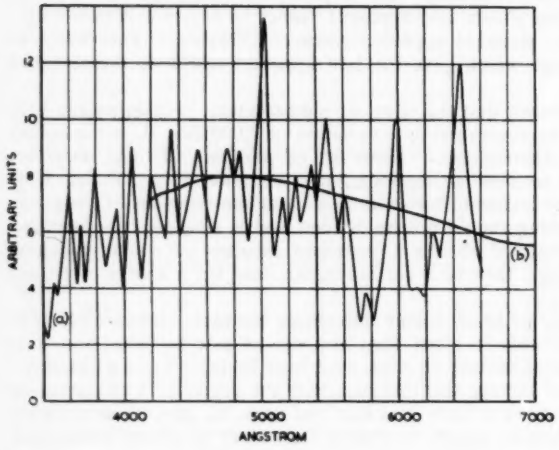


*Fig. 2. Spectral energy distribution of*
*(a) Carbon dioxide lamp.*
*(b) Overcast sky (6,500 deg. K).*

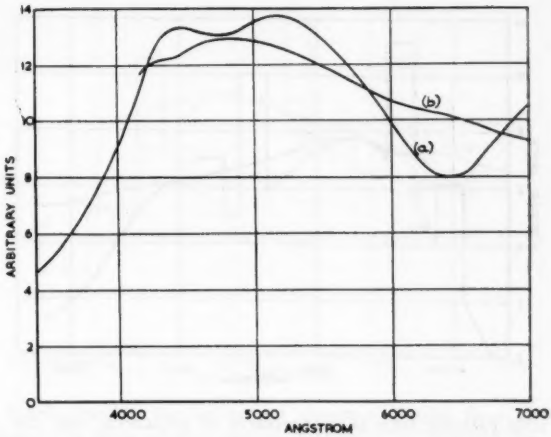


*Fig. 3. Spectral energy distribution of*
*(a) 2,900 deg. K tungsten filament lamp with Chance OB8 filter.*
*(b) Overcast sky (6,500 deg. K).*

with a suitable filter have the great merit of simplicity. Two types of colour matching units using this principle have found application in industry. The Lamplough is a British unit employing a 1 kw. lamp in a closed fitting, and uses a combination of glass filters to produce a spectral distribution close to that of a full radiator at 6,500 deg. K. The Macbeth unit is of American origin, and uses several high-wattage lamps in a large enclosed diffusing fitting, having forced cooling, and filters to obtain a spectral distribution similar to a full radiator at 7,500 deg. K. The spectral energy distribution of a similar unit using a 1 kw. 230-volt lamp (colour temperature approximately 2,900 deg. K) and Chance OB8 filter is shown in Fig. 3, compared with the curve for an overcast sky at 6,500 deg. K.

While these sources have proved very reliable for accurate colour matching work, the undesirable effects of low efficiency (about 3 lm/w for the 1 kw. unit) and high heat radiation are present, although the large units have heat absorbing filters and probably represent the most suitable sources for many purposes which have yet been marketed.

The colour temperature of a tungsten filament lamp varies with the supply voltage, a 5 per cent. drop in voltage causing a 50 deg. K drop in colour temperature of the lamp. This variation produces a change in colour temperature of the filtered light from 6,500 deg. K to 6,300 deg. K. It is probable that with the simultaneous viewing of the sample and the standard, variations of this type do not present a serious embarrassment in practice.

Careful attention must be given in these units to the internal finish of the fitting, as any discoloration of the reflecting surface due to heating or age modifies the resultant colour considerably.

The difficulties associated with the low efficiencies are to a large extent obviated with the use of a fluorescent discharge tube source. A mixture of fluorescent phosphors, having different spectral distributions, can be incorporated into a lamp to give a spectral distribution close to that required and have an efficiency of 45 lm/w. The spectrum of the radiation emitted is mainly a continuum with a component due to the direct line radiation from the mercury discharge (Fig. 4). The curve for 6,500 deg. K overcast sky is included for comparison.

A specially made colour matching unit incorporating cold cathode fluorescent tubes and carefully selected colourless mirror glass reflectors has been made commercially for the past 10 years[16]. Apart from its high efficiency, the life of the

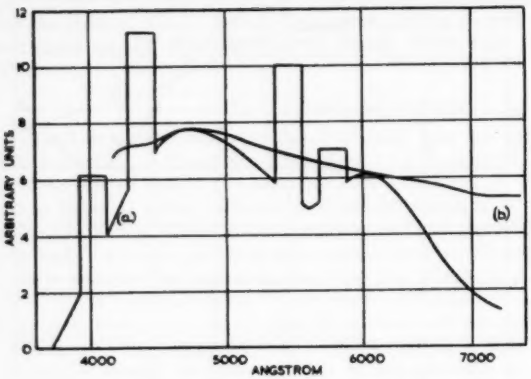


*Fig. 4. Approximate distribution of energy in*
*(a) The spectrum of an 80-watt colour matching fluorescent lamp.*
*(b) Overcast sky (6,500 deg. K).*

cold cathode tube is independent of switching, and the mirror glass reflectors ensure that there is no colour distortion in the fitting, either initially or during life. The cold cathode tube was followed in 1948 by the introduction of a similar colour into hot cathode tubes which are now available in all sizes from 18-in. 15-watt to 5-ft. 80-watt. For matching samples having closely similar reflection characteristics, the fluorescent tube source has proved quite satisfactory and also has the advantage that the tube can readily be incorporated in a fitting to give a large diffuse source of uniform brightness. The same type of tube can also be used for general illumination to reduce any distortion due to colour contrast. As can be seen from Fig. 4, the fluorescent tube is slightly deficient in red compared with a full radiator at 6,500 deg. K. This can be corrected by the use of deep red phosphors such as magnesium arsenate or magnesium fluogermanate[15] in the coating. This additional red radiation can only be achieved by replacing some of the blue phosphors in the mixture, which gives rise to a greater distortion in the rendering of blue materials due to the increasing proportion of mercury line radiation at the blue end of the spectrum.

The effect of the line radiation and other departures from full radiator emission in the mercury discharge becomes increasingly important as the accuracy of matching increases. The main difficulties arise with colours reflecting in the deep blue, where the radiation from the 4,047 Å and 4,358 Å lines becomes important. It is unfortunate that no practical filter is available which is selective enough to deal with these mercury lines. Their effect can, however, be reduced by increasing the contribution of the blue radiation from the phosphor coating and making up the resultant red deficiency with tungsten filament lamps, as described later.

The long-wave ultra-violet output of the colour matching fluorescent tube is only about half that of daylight, and for this reason daylight is preferred for examining materials having a fluorescent constituent.

An improved spectral distribution can be obtained, whilst maintaining a reasonable luminous efficiency, by mixing the light from a tungsten filament lamp and special blue fluorescent tube. This reduces the effect of the mercury line radiation to a minimum, while the deficiency at the red end of the spectrum is made up by the radiation from the tungsten lamp. A unit of this type has been described by Harrison[17]. In such units using mixed light from very dissimilar sources, it is necessary to take great care to obtain a uniform spectral composition over the working field. The authors suggest that the ability to vary the effective colour temperature by varying the ratio of fluorescent to tungsten light could be used to compensate for the variations between observers mentioned earlier. With the aid of a test scale

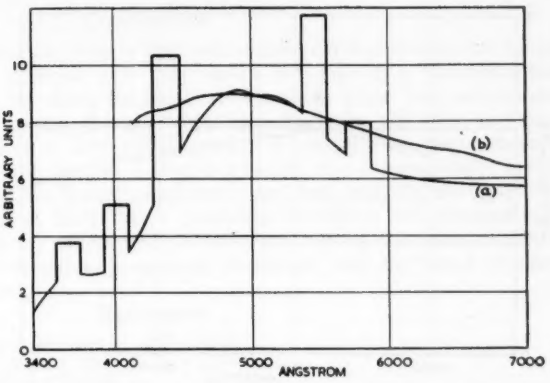


*Fig. 5. Spectral energy distribution of*
*(a) New colour matching unit.*
*(b) Overcast sky (6,500 deg. k.).*

similar to that described by Warburton[12], the individual observer should then be able to bring his observed match to that of the average observer in daylight by varying the colour temperature of the source, and to maintain this colour during the lives of the component lamps and for any variation in mains voltage. The energy radiated by the fluorescent tube can also be arranged to extend into the long wavelength ultra-violet and have an ultra-violet output comparable to that of daylight. This combination can be used for comparing fluorescent whites and other materials having a fluorescent component. The spectral energy distribution of a unit of this type in shown in Fig. 5, together with the spectral distribution curve for a 6,500 deg. K overcast sky. Table I shows the percentage of ultra-violet radiation between 3,200 Å and 4,100 Å in the various sources discussed in this paper. Table 2 shows the ratios of line to continuum in this source compared with a colour matching fluorescent tube.

It has been known for some time that under special conditions of excitation it

**Table 1.**

| Source | Percentage near u.v. (3200-4100Å) emitted |
|---|---|
| Lightly overcast North skylight | 14 |
| Lightly overcast North skylight through window glass | 11.5 |
| Full radiator at 6500 deg. K | 20 |
| 1 kw filament lamp at 2900 deg. K, and OB8 filter | 10 |
| Xenon arc | 19 |
| Carbon dioxide unit | 16 |
| Colour Matching fluorescent tube | 7.5 |
| Colour Matching unit as described | 11 |
| Standard Illuminant A (2854 deg. K) | 2 |

**Table 2.**

| Source | Percentage mercury line radiation in region 4000-4400A |
|---|---|
| Colour Matching fluorescent tube | 45 |
| Colour Matching unit as described | 40 |

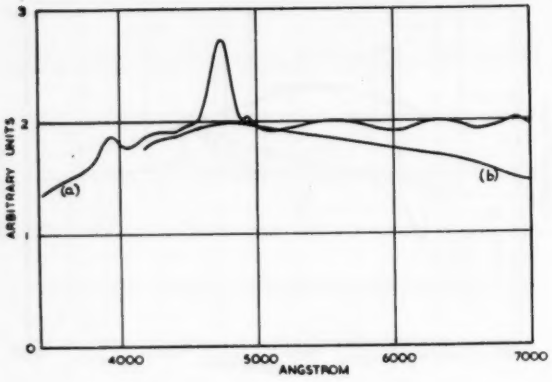


*Fig. 6. Spectral energy distribution of*
*(a) 1-kw. high pressure compact source xenon lamp.*
*(b) Overcast sky (6,500 deg. K.).*

is possible to obtain near full radiator emission from a discharge through rare gas and, in particular, xenon. The electronic photographic flash discharge lamp is a familiar example. This principle has been applied in continuously operating lamps[18, 19]. At gas-filling pressures around 1 atmosphere, the effective colour temperature of the source is about 5,250 deg. K, and the luminous efficiency about 25 lm/w. More recently, lamps of this type with a filling of about 10 atmospheres of xenon have been developed in Germany[20]. The colour temperature of these sources is close to 6,150 deg. K and the efficiency around 30 lm/w. The lamps are made in 160 watts, 500 watts and 1 kw. ratings and are finding some application for colour matching despite their high cost and the complexity of the associated control equipment. The spectral energy characteristics are given in Fig. 6, together with that of an overcast sky at 6,500 deg. K. Owing to the compact nature of the source it does not readily lend itself to providing a large diffuse source area.

Although the lamp efficiency is fairly high, the lamp is usually operated from a D.C. supply with a series resistor to obtain a reasonable life, and this reduces the overall efficiency to around 8 lm/w. A typical operating circuit is shown in Fig. 7, where a high-voltage pulse is provided for the initiation of the arc. Operation on A.C., using inductive control of the current, gives higher overall efficiencies, but is not often used because of the poor life performance of the lamps on A.C. This applies particularly to the highly loaded short arc-length lamps. It is worthy of note that a 1 kw. tungsten lamp in association with an appropriate filter to give the same colour temperature gives about 3 lm/w.

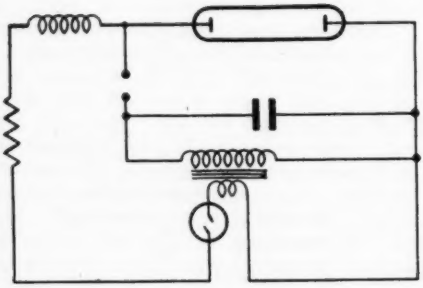

*Fig. 7. Typical operating circuit for 1-kw. high pressure xenon lamp.*

## Conclusions

Although daylight is still the most widely used source of illumination for colour matching, experience with artificial units has shown that, where a non-metameric match is required, colour matching fluorescent tubes have come into widespread use because of their good colour characteristics, high luminous efficiency and convenient source shape. Where a very critical match is required, or where there is a fluorescent component in the sample, a filtered tungsten unit is appreciably better, but has the disadvantages of low luminous efficiency and high heat radiation. Where high efficiency is required it is likely that a combined fluorescent and tungsten unit having an increased ultra-violet output and facilities for varying the effective colour temperature to take into account any observer variations, will be found to meet the majority of requirements.

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## Discussion

MR. W. HARRISON: I would first compliment the authors on producing a concise and easily readable paper and one which I think presents a fair picture of to-day's colour matching illuminants. In opening the discussion I would like to underline one or two points they have made and then to add some suggestions for possible developments.

The first point is the minutely fine limits to which the colour matcher works. I have brought four samples of fabric which have small colour differences and I am assured that none of them would be acceptable as a match for any of the others. The colour matcher must work to such fine limits all the time, and obviously the intensity of illumination under which he works must be comparable with that given by natural light.

The second point is that the spectral quality is vital. Natural light at a given colour temperature always has the same spectrum, whether, for example, in Manchester or the Mediterranean. I mention Manchester and the Mediterranean because it has been found by experiment that their light is the same (ref. P. W. Cunliffe, J. Text Inst., 1929, **20**, T34). No artificial illuminant quite simulates the daylight spectrum and the measure of approximation achieved is a measure of the goodness of a colour matching illuminant.

Commenting on illuminants mentioned in the paper, the filament lamp with

OB8 filter has inevitably a low lumen per watt efficiency, but I have wondered if a better utilisation of the lumens could be obtained if the lamp were made in the spotlight reflector bulb. A 500-watt lamp, for example, in that bulb would give a reasonable illumination of a small bench area.

The combination of light blue fluorescent and incandescent light may be regarded as one form of "Blended Light," a development which is coming along in several forms. So far the combination of blue fluorescent and incandescent has, I think, been applied commercially only in colour matching units, but perhaps it could be extended to general lighting where artificial daylight or sunlight of excellent spectral quality is required. By adjusting the proportions of fluorescent and incandescent, any desired colour temperature can be obtained at a reasonable efficiency and lamp cost. For example, two 80-watt light blue fluorescent lamps in combination with four 150-watt or 200-watt incandescent lamps give sunlight quality at nearly 20 lumens per watt. Only the xenon arc can give a comparable spectrum and efficiency, and I suggest that a room lighted with this combination would have an effect which could be described as exhilarating, a term which has been applied to xenon lighting.

MR. R. E. WILSON: I should like to congratulate the speakers on the excellent paper and I should like to say how much I appreciated the demonstrations.

It might be as well to outline the essential requirements from the dyer's point of view of a daylight matching lamp.

(1) The quality of the light should be as closely as possible identical with that from a slightly cloudy sky at noon, viewed in a northerly direction. (2) The luminosity should be of a high order. (3) The quality of light and the luminosity should be uniform over the field of view. (4) The quality of light should be adequate for the matching of fluorescent samples. (5) The lamp should be cheap and require low maintenance charges. There should be a reasonable life and low replacement costs. (6) The difference between units should be less than one step on the ladder range of patterns, as used by Dr. Warburton in the Leeds Exhibition of a few years ago. (7) There should be an adequate control on the lamp, so as to ensure constant quality of light as measured by the ladder range.

Dyers are being more frequently asked to match samples in white or colour containing fluorescent compounds; this is possible in daylight, but not in tungsten light. The brilliance of the fluorescent samples is not visible in tungsten light and, therefore, much of the work of the dyer, and, incidentally, of the launderer and detergent manufacturer, is wasted if artificial light does not possess an ultra-violet component capable of showing the presence of such fluorescent compounds.

I very much appreciated the demonstration with the ladder range in which members of the audience were asked to indicate their own idea of a match to the "standard" pattern. In our experience, most ladies match this pattern in the region of 9 to 12 or 13, whereas most experienced dyers would find a match in the region 8 to 9. This could possibly explain why ladies are so difficult to satisfy in their demands for colour.

MR. F. L. WARBURTON: I should like to congratulate the authors on this very useful survey of the requirements of artificial daylight for colour matching and of the equipment available to-day. This will prove very useful not only to users and suppliers of such equipment, but to everyone who has to advise on the use of daylight lamps.

I should like to ask the authors their opinion as to the future possibilities of the xenon lamp. This was being enthusiastically advertised by German manufacturers and their agents a few years ago, but it proved very difficult to get any reliable technical information.

I would agree very strongly with the authors in stressing the importance of good

general illumination of rooms used for colour matching, with light of good daylight quality resembling that of the actual colour matching lamp. The ordinary colour matching fluorescent tube is ideal for this purpose on account of its relative cheapness. With this lamp it is not necessary completely to exclude the general illumination from the actual colour matching area, even when a colour matching lamp approaching more closely to the theoretical ideal is employed.

In my experience, the colour matching fluorescent tube is sufficiently good for most colour matching even with metameric pairs, but there are occasions when it is inferior to the other types mentioned by the authors. Red and pink dyes on rug wools and acetate rayons are particularly affected, most of the errors which I have met being attributable to the low luminance of the fluorescent tube in the extreme red.

The tungsten lamp-filter combination has the disadvantage of low light output even when two 1,000-watt lamps are used. If higher wattages are employed, the already low efficiency is reduced by the necessity for fan cooling, which also adds to the capital cost. As the authors point out it does however approach more closely to the theoretical ideal than any other lamp. At an exhibition of daylight lamps held in Leeds some years ago this lamp was preferred by most visitors to all other colour matching lamps except the blended fluorescent and tungsten lamps, which were about equally popular.

I like the suggestion that the blended lamp should be used with some form of dichroic ladder to compensate for variations in colour vision. This would obviate one of the great difficulties in standardisation of the observer—namely, the risk of an observer becoming unsuitable with increased age. There is insufficient data for knowing how great may be the change in colour vision with age for individual observers.

As regards the actual colour temperature to be standardised, I would agree with the remarks made by Mr. Ruff at the 1948 C.I.E. meeting (C.I.E. Compte Rendu, 1948, p. 55), that the choice of a higher colour temperature than 6,500 deg. K has been determined by the search for the most constant phase of daylight available indoors rather than by any supposed correspondence with the ultimate user conditions. A. C. Hardy (Handbook of Colorimetry, p. 18, M.I.T., 1936) suggests that the total light (sky and sun) falling on a horizontal surface is independent of the natural meteorological conditions, and corresponds to that of sun outside the earth's atmosphere (6,500 deg. K). Nickerson's work was concerned chiefly with non-metameric matches, and determined mainly the conditions giving the greatest all-round colour discrimination. I would point out that the effect of variations in colour vision, calculated from my results, refers to an incident illumination of 4,800 deg. K. If the macular pigment behaves as an approximate colour temperature filter, the effect in terms of colour temperature will be doubled at 6,500 deg. K, i.e., $\pm$ 500 deg. K instead of $\pm$ 250 deg. K, with correspondingly less stringent requirements in the lamps.

Dr. R. W. Hunt: The authors have dealt comprehensively with the colour matching light sources of to-day, but I was a little disappointed that no reference was made to a light source of yesterday, namely, the Blue Glass "Daylight" tungsten lamp in which I have a particular interest at the moment.

I would like to know whether the colour transmission curve of this lamp differs to any great extent, and at any particular points, from the limits of the daylight transmission curves shown in slide No. 2, and whether or not this type of lamp has any practical use or value in colour discrimination work. I would, if possible, like to see the transmission curve of this lamp superimposed on the daylight colour transmission curves.

On a second point, I naturally assume that the skilled observers chosen for colour discrimination and colour matching work are subjected to stringent colour vision

examinations based on one or other of the various tests. It would be helpful, and I would be interested to know, what form of light source the authors of the paper would recommend for illuminating the test charts or cards used for this purpose.

MR. S. S. BEGGS: I wonder if the authors could give us some indication of the variation of the different sources, both with age and from batch to batch. My own experience with coloured glasses has been that it is very difficult to repeat a colour exactly, as would appear necessary with the filtered incandescent lamp unit. Where different types of lamp are used in combination, does not difference in their characteristics cause change of spectral composition with age? The carbon-dioxide tube would appear to be the source of most stable spectral distribution, since the discharge has a fundamental physical nature. but even this may be affected if helium is also used in the tube.

I should also be interested to know whether for certain purposes in which the products will almost certainly be used in artificial light, for example, materials for evening dresses, light of a lower colour temperature is used, as would seem more reasonable than the use of daylight.

MR. F. P. BENTHAM: The paper tells us what most have suspected for a long time, that the problem of colour rendering, and therefore colour matching, under artificial light has not been solved. It is particularly desirable to have an objective survey such as this, which does *not* end up with the author's pet panacea. I would particularly like to make this paper and others like it compulsory reading for high pressure salesmen and publicity merchants.

After using a term such as "colour matching" for the present imperfect tubes, what are you going to call the perfect tube when it comes along. Fluorescent lamps have a fatal attraction for extravagant claims. Such claims confuse the user and often one finds in shops and stores tubes of so-called colour matching properties, where in fact tungsten is more appropriate. After all, it is still a fact that where we display our dress finery the lighting is likely to be very low level tungsten of uncertain age, or if by chance fluorescent, then of a glamourised, near civilised colour.

THE AUTHORS (in reply to the discussion): We fully agree with Mr. Harrison's comments on the close limits to which the colour matcher works. We note with interest his suggestion that a more efficient tungsten lamp unit might be constructed around a reflector spotlight, but point out that the illumination on a horizontal plane from this type of lamp is very non-uniform and if a diffusing screen is used in front of the lamp to overcome this difficulty the overall efficiency is appreciably lower than can be obtained from a well-designed fitting using normal lamps.

The potentialities of the 10 atmosphere xenon lamp mentioned by Mr. Warburton are considerable, but its use is restricted by the high cost of the lamp and the rather elaborate control gear required to operate it. The losses in the control gear, particularly when D.C. is used, as is generally the case, are high, resulting in poor overall efficiency.

The daylight blue lamps referred to by Mr. Hunt are still manufactured and the colour temperature is about 4,800 deg. K. Although the spectral distribution of light from these lamps is similar to that of a full radiator at 4,800 deg. K, it is not practicable in a tungsten lamp bulb to control the colour and thickness of the glass to the fine limits to which the optical filters used in tungsten filament lamp units are controlled. We are not very familiar with the ophthalmic methods used for checking the various forms of colour blindness, but in the Ishiara tests daylight is recommended and it is

likely that any source having similar characteristics would be acceptable for viewing these printed charts.

In reply to Mr. Beggs, the technique employed in the fine control of colour in glass filters of the type described in the paper is to grind the filters to the thickness required to give the correct final result. With the single lamp fittings there is little change in colour with age, but with the combined units the differential lumen maintenance can cause a drift in colour. This difficulty, together with other factors affecting the final colour, can be eliminated if separate controls are provided for each type of lamp and the colour set on each occasion of use by a particular observer with the aid of a colour ladder of the type described in the paper. Checking of colour under low temperature artificial light is often done by colorists, particularly when the articles are to be used under these sources, but the provision of a source of this type for colorists' use presents no difficulty.

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